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WELL COOLER

DESCRIPTION

The invention relates to a well cooler for cooling a cooling medium of a driving unit on a ship, such as a marine motor, by means of outboard water, which well cooler can be placed in a well space present in the ship, which lies at least partially below the outboard water level and which is in open communication with the outboard water, the well cooler comprising at least one cooling element for the cooling medium, which extends into the well space and which is surrounded by outboard water during operation, and the ship furthermore being provided with a cathodic corrosion protection system.

Well coolers of the above kind have been known for quite some time already, they are used in particular for cooling marine motors, such as propulsion motors, generator motors, pump motors and auxiliary motors, which are generally present on a ship. It is the effective utilisation of the outboard water as a continuously supplied coolant for the cooling medium (motor water) of the various driving units that makes such a well cooler functional.

The outboard water enters the well space via an opening and flows round the cooling element of the well cooler. The hot cooling medium of the driving unit is passed through the cooling element and cooled by the outboard water through heat transfer. The cooled-down cooling medium is returned to the driving unit, whilst the outboard water can exit the well space via another opening. As a result of the colder outboard water being heated by the hotter cooling medium, an upward outboard water flow occurs in the well space. Thus, the inlet opening(s) and the outlet opening(s) for the outboard water in the well space are usually provided at different levels in the wall of the well space.

A generally known phenomenon with ships is their susceptibility to fouling by algae and other aquatic organisms, such as

cockles and mussels, on those parts of the ship in that are in contact with the outboard water. To limit the extent of fouling on the ship's hull as much as possible, the hulls of most ships are provided with an antifouling coating.

If said antifouling coating gets damaged, local corrosion will occur on the ship's hull at the places where the coating is damaged. To prevent such local corrosion of the ship's hull, a cathodic corrosion protection system is used.

Also the cooling element, which is disposed in the outboard water, is in principle susceptible to fouling by algae, which in time affects the cooling efficiency of the well cooler. The use of the copper alloy CuNi10Fe (CopperNickel 90/10) as the material for the bundle of the well cooler strongly reduces the extent biological growth. This effect is the result of the natural properties of this specific material. In order to achieve this effect, the well cooler must be mounted in such a manner that it is completely insulated from the ship's hull. This makes the well cooler more susceptible to corrosion caused by stray currents in general, however, which stray currents may or may not be caused by the cathodic corrosion protection system with which the ship is provided.

The main cause of the increased risk of attack is the fact that a well cooler has a relatively vast heat-exchanging area made up of a bright or uncoated metal surface in a conductive medium.

The object of the invention is to provide a well cooler of the above kind which exhibits an effective cooling efficiency, which is hardly susceptible to biological growth, if at all, in the long run and which is not affected by stray current corrosion, which reduces the life span of the well cooler.

According to the invention, the well cooler is provided with means that prevent the cooling element from being affected by stray current corrosion. As a result, a well cooler is obtained which is optimally protected against corrosion caused by stray currents, and which

consequently has a longer life span, without the cooling capacity of the well cooler being adversely affected.

In a special embodiment, said means are accommodated in the well space, more specifically, said means surround the cooling element at least partially.

In a specific embodiment, said means are at least partially pervious to the outboard water so as not to affect or impede the cooling action of the well cooler.

More specifically, said means are made of an electrically conductive material.

It has become apparent that the cooling element can be prevented from being affected by stray current corrosion in a very effective manner in that, in a special embodiment of the invention, said means are formed by a metal mesh.

In a special embodiment, said means are electrically insulated from the electric corrosion protection system, whilst in another embodiment said means are electrically connected to the electric corrosion protection system. In both embodiments an effective protection of the cooling element against stray current corrosion is obtained, whilst in the latter embodiment also the stray currents passing through the outboard water are effectively discharged to earth. In the electrically insulated embodiment, this prevents stray currents from accumulating in the form of static charge in said means in special situations, which static charge may discharge in the direction of the cooling element or other parts of the well cooler in unforeseen, adverse conditions and lead to stray current corrosion yet.

The invention also relates to an electric corrosion protection system for use on a ship provided with the means as described in the present patent application.

The invention furthermore relates to a ship provided with an electric corrosion protection system comprising the means as described

in the present patent application.

The invention will now be explained by way of example in the description below, in which reference is made to a drawing, in which:

Fig. 1 is a schematic, sectional view of a ship provided with a well cooler according to the prior art;

Fig. 2 is a more detail view of a well cooler according to the prior art;

Fig. 3 schematically shows the effects caused by a cathodic corrosion protection system used with a well cooler according to the prior art;

Fig. 4 shows a first embodiment of a well cooler according to the invention;

Fig. 5 shows a second embodiment of a well cooler according to the invention;

Fig. 6 shows a test setup for testing the effects caused by a cathodic corrosion protection system used with a well cooler according to the prior art and with a well cooler according to the invention; and

Fig. 7 shows a table with measuring results obtained with the test setup of Fig. 6.

For a better understanding of the invention, like parts are indicated by the same numerals in the description below.

Fig. 1 shows a ship provided with a well cooler that is known from the prior art. The ship 1 has a closed well space 2 within the ship's hull 1a, which space is in open communication with the outboard water 8 via one or more inlet openings 7a and outlet openings 7b.

A well cooler 3 can be placed in the well space 2 via an opening 3a, which opening can be closed by means of a pipe plate 6. A known embodiment of a well cooler according to the prior art is shown in Fig. 2. The known well cooler 3 is provided with a cooling element 4 that is built up of a large number of a vertically disposed bundle pipes 5. Said bundle pipes 5 are fixed in the pipe plate is 6 with their one end

5a as well as with their other end 5b. The pipe plate 6 is provided with an inlet 7a and an outlet 7b for a cooling medium (cooling water) for a driving unit of the ship.

The term driving unit as used herein is understood to include propulsion motors, generator motors, pump motors and auxiliary motors that can be used on a ship.

Since such driving units are generally operated at full power on a ship, it is essential that said driving units be adequately cooled. To that end the cooling medium (cooling water) having a high operating temperature is carried into the bundle pipes 5 via the inlet 7a and said one ends 5a. The cooling medium is pumped through the bundle pipes 5 in the direction of the other ends 5b and the outlet 7b, after which it is returned to the driving unit.

During operation, the outboard water 8 present in the well space 2 flows round the vertically disposed bundle pipes 5. The difference in temperature that generally prevails between the hotter cooling medium in the bundle pipes 5 and the outboard water results in heat being transferred to the outboard water, which is thus heated up. As a result of the outboard water flowing round the bundle pipes 5, the hotter cooling medium that flows through the bundle pipes 5 is cooled down and subsequently the cooled-down cooling medium exits the well cooler 3 in the direction of the driving unit via the outlet 7b.

The heated outboard water moves upward during said process, resulting in an upward convection current of outboard water in the well space 2. As a result of the vertical convection current of the outboard water 8 thus created in the well space 2, the inlet openings 2a and the outlet openings 2b are provided at different levels in the ship's hull, with the outlet openings 2b being positioned at a higher level, closer to the outboard water level. Thus an upward flow of entering outboard water 8a (having a low temperature) and an exiting flow of outboard water 8b (having a higher temperature) is created in the well space 2 during

operation.

On the other hand, the flow of the outboard water 8 through the well space 2 is forced while the ship is sailing.

In order to realise a strong, stable construction of the well cooler 3, which is built up of a large number of bundle pipes 5, the well cooler 3 is furthermore provided with horizontally extending supporting plates 9, which interconnect the bundle pipes 5. Although a stable construction of the well cooler 3 is obtained in this manner, the horizontally extending supporting plates 9 form an obstacle to the upward flow of outboard water created by heat convection.

A generally known phenomenon that occurs with ships is their susceptibility to fouling by algae and other water organisms, such as cockles and mussels, on those parts of the ship that are in contact with the outboard water. In order to limit the extent of fouling on the ship's hull as much as possible, the hull of most ships is provided with an antifouling coating.

If said antifouling coating gets damaged, corrosion will occur at the location on the ship's hull where the coating is damaged. In the case of damage to the antifouling coating, the corrosion on the ship's hull is concentrated at a specific location (local corrosion), in contrast to (general) corrosion, in which a material is affected by corrosion in an evenly distributed manner over the entire surface area thereof. In order to prevent the ship's hull being locally affected by corrosion, use is made of a passive corrosion protection system, possibly in combination with an active corrosion protection system.

A passive corrosion protection system consists of a calculated number of anodes (e.g. of zinc or aluminium), which are mounted in metallic contact with the ship's hull.

An active cathodic corrosion protection system comprises an external current or voltage source between a cathode and an anode, which creates an external potential field around the ship. Said external

potential field is also present in the outboard water, so that a (weak) electrical current will start to flow through the outboard water under the influence of ionic flux. Said current enters the ship via the locally damaged spots in the antifouling coating. Since the ship's hull is electrically connected to the active cathodic corrosion protection system, the active cathodic corrosion protection system prevents the occurrence of local corrosion at the specific damaged locations where the induced current enters the ship's hull.

Outboard water continuously flows round the cooling element 4 of a known well cooler 3 according to the prior art that is present in the well space 2, and consequently said cooling element is highly susceptible to fouling by algae, cockles, mussels or other aquatic organisms. Although some local fouling on the cooling element 4 does not necessarily have an adverse effect on the cooling efficiency of the well cooler 3, the cooling capacity of the well cooler 3 decreases strongly when the entire cooling element, which is built up of a large number of bundle pipes 5, is fouled, and in particular when all kinds of fouling has lodged between the many bundle pipes 5.

In this latter situation the through-flow of the outboard water through the bundle of bundle pipes is seriously obstructed, if not blocked altogether, as a result of which the cooling capacity of the cooling element 4 is lost substantially completely. It is known, therefore, to provide the cooling element 4 with a protective and insulating coating on the outboard water side in combination with a system consisting of electrically activated copper bars.

Said bars slowly dissolve, creating a toxic environment for biological organisms around the coated bundle pipes. The protecting and insulating coating has a strongly adverse effect on the transfer of heat from the hotter cooling medium to the colder outboard water, which in turn has an adverse effect on the cooling efficiency. In addition to that, the protecting and insulating coating reduces the surface

temperature of the bundle pipes, as a result of which said bundle pipes are more susceptible to possible fouling by biological organisms.

A better protection against fouling on the cooling element 4 (the bundle pipes 5) by algae etc can be achieved by making the cooling element 4 of a material that has a natural resistance against fouling by biological organisms (such as CuNi10Fe) and which completely insulates the well cooler 3 electrically from the rest of the ship.

Although this electrically insulated arrangement of the well cooler 3 with respect to the rest of the ship, including the cathodic corrosion protection system, strongly reduces the extent of fouling by algae etc, the cooling element 4, and more in particular the large number of bundle pipes 5, are confronted with a different form of corrosion, viz. stray current corrosion.

Stray current corrosion is a form of local corrosion on a part of the ship, which is caused by the transfer of charge at the interface between the material and its environment as a result of the presence of an external current or voltage source or by an externally generated potential field, for example the external potential field generated by a cathodic corrosion protection system.

The phenomenon of "stray current corrosion" will now be explained with reference to Fig. 3.

Fig. 3 shows a vessel filled with outboard water 8 which, figuratively speaking, represents the sea. The positive electrode 11 (anode) and the negative electrode 12 (cathode) are connected to a cathodic corrosion protection system 10 via respective connections 11a-12a. This system 10 creates an external potential field 13 in the outboard water 8 between the electrodes 11 and 12. The arrows in Fig. 3 indicate the field line orientation of the electric potential field 13.

Reference numeral 4 schematically indicates the cooling element 4 of a well cooler 3, which cooling element 4 is accommodated in a well space 2, being completely insulated electrically from the ship and

the cathodic corrosion protection system, with outboard water 8 flowing all around the cooling element. Part of the flow of charge between the electrodes 11 and 12, which usually takes place via the outboard water (sea water) as a result of ionic flux, will now take place via the metal of the electrically insulated cooling element 4. The influx of ions between the positive electrode 11 and the metal of the cooling element 4 at the location indicated at A in Fig. 3 leads to the following reduction reactions (1) and (2) at the metal surface:

$$O_2 + 2\ H_2O + 4\ e^- \Rightarrow 4\ OH^- \qquad (1)$$

$$2\ H_2O + 2\ e^- \Rightarrow H_2\ (gas) + 2\ OH^- \qquad (2)$$

These reduction reactions (1) and (2) can occur at the metal surface because the potential in the outboard water quite close to the metal surface is (much) higher than the potential of the metal. The flow of charge in the metal of the cooling element 4, which is electrically insulated from the ship, takes place through electron conduction.

Subsequently, the ionic flux will exit the metal 4 near B and enter the outboard water 8 in the direction of the negative electrode 12. Said outflux of ions leads to oxidation reactions, which can take place in that the potential of the outboard water 8 directly at the metal surface, at the location indicated B in Fig. 3, is (much) lower than the potential of the metal material. The oxidation reaction that takes place substantially at the metal surface is the oxidation of the material in accordance with the following reaction equation (3):

$$M \Rightarrow M^{n+} + n\ e^- \qquad (3)$$

In accordance with this reaction equation (3), metal ions dissolve from the metal surface into the outboard water 8. As a result of this metal dissolving reaction (3) the metal surface dissolves, as it were: the metal surface is attacked by corrosion. In the outboard water 8 the flow of charge takes place in the direction of the electrode 12, again by ionic flux.

As a result of the presence of an external potential field as set by a cathodic corrosion protection system (Impressed Current Cathodic Protection: ICCP), the metal parts that are electrically insulated from the cathodic corrosion protection system and that are placed in said potential field are subject to very rapid attack by stray current corrosion.

According to the invention, the ship, and more in particular the known well cooler, is provided with means which prevent this attack by stray current corrosion.

A first embodiment is shown in Fig. 4, in which the means that prevent attack of the cooling element 4 by stray current corrosion are indicated by numeral 14. According to the invention, said means 14 are accommodated in the well space 2, surrounding the cooling element 4 at least partially.

In order not to affect the cooling capacity of the cooling element 4, the means 14 are at least partially pervious to the outboard water 8. The means 14 are in particular made of an electrically conductive material, more in particular of a metal mesh that surrounds the cooling element 4.

Said mesh 14 functions as an electrical screen, which prevents the influx of ions into the metal of the cooling element 4 as a result of the presence of the generated external potential field between the positive electrode 11 and the negative electrode 12 of the cathodic corrosion protection system 10.

By providing an electrical screen in the form of a metal mesh around the cooling element 4 of the well cooler 3, the potential differences across the cooling element 4 disposed in the external potential field are strongly reduced. Thus, no stray current can flow through the metal of the cooling element 4, which stray current thus cannot exit, either, and will not cause any stray current corrosion.

Fig. 5 shows another embodiment, in which the metal mesh 14

that fully surrounds the cooling element 4, which is electrically insulated from the ship, is furthermore electrically connected to the cathodic corrosion protection system 10 of the ship by means of an electrical connection 14a.

In an analogous manner as in Fig. 4, the potential differences across the metal surface of the cooling element 4 are strongly reduced as a result of the provision of a metal mesh 14 around the cooling element 4. Thus, no stray current can be induced in the metal of the cooling element 4, and no stray current can exit the metal in the direction of the negative electrode 12 near a point B, therefore. Thus, corrosion caused by stray currents can be prevented in an effective manner.

By electrically connecting the metal mesh 14 to the cathodic corrosion protection system 10, the stray currents entering the mesh 14 (see the arrows in Fig. 5) are effectively diverted as a result of said electrical connection to the negative electrode 12 (cathode).

In another embodiment, the means which, according to the invention, prevent the cooling element 4 from attack by stray current corrosion consist of a cylindrical or tubular envelope, which can be provided round the cooling element 4 and which is closed by a metal mesh at both ends.

Fig. 6 schematically shows this other embodiment according to the invention, wherein furthermore the effects of the various aspects on the external potential field, and consequently the occurrence of any stray current corrosion, can be measured in a very effective manner.

In this embodiment, the well space 2 is schematically formed by a cylindrical tube portion 1a, which represents the ship's hull 1a. The two short open ends of the cylindrical tube portion 1a form the inlet opening 7a and the outlet opening 7b, respectively, for the outboard water 8. The two inlet and outlet openings 7a-7b are closed by means of a metal mesh 14a-14b. As a result of this construction, outboard

water 8 can flow through the entire cylindrical tube portion 1a.

The cathodic corrosion protection system 10 applies an external potential field by means of the positive electrode 11 (anode) and the negative electrode 12 (cathode). Using the contact electrodes 15a-15b, the potential field applied between the two electrodes 11 halves and 12 can be measured by means of voltage meter V_2.

Two metal elements are placed in the tube portion 1a, which elements are electrically insulated from the rest of the setup. The two metal parts 4a-4b are interconnected by means of a current meter A_1. Contact electrodes 16a-16b are furthermore disposed in the tube portion 1a that functions as the well space 2, which contact electrodes are interconnected by means of a volt meter V_1.

The two metal meshes 14a-14b are electrically interconnected by means of a connection 18 and, in addition to that, they may be electrically connected to or be insulated from the cathodic corrosion protection system 10-11-12 by means of a switch 17.

Using this measurement setup, a number of measurements have been carried out for various situations. Within the framework of these measurements, an electrical potential field is realised between the positive electrode (anode) 11 and the negative electrode (cathode) 12, wherein the potential differences across the well space 2 (the tube portion 1a) can be measured by means of the contact electrodes 15a-15b and the volt meter V_2. During the test measurements, the electrical potential field was increased from 0 to 1000 mV in steps of 100 mV.

With each externally applied potential field, the potential difference in the well space 2 and across the two metal parts 4a-4b will be measured (in millivolt) under different conditions by means of the contact electrodes 16a-16b.

In the first measurement, the two ends 7a-7b of the cylindrical tube portion 1a are fully open, so that the space 2 and the rest of the outboard water are in open communication. As a result of this

open measuring situation, the external potential field will exhibit the same potential difference at all locations, measured both outside (V_2) and inside (V_1) the tube portion 1a. In Fig. 7 this is shown by the histogram that is indicated "without screen" in the legend.

In the second and third measurements a coarse mesh 14a-14b is used as the stray current screen. When the switch 17 is open, i.e. the situation in which the screening means 14a-14b are not connected to the cathodic corrosion protection system 10 (indicated "disconnected"), higher potential differences are measured between the contact electrodes 16a-16b in the tube portion 1a than in the situation in which the switch 17 is closed and the screening means 14a-14b are electrically connected to the cathodic corrosion protection system 10.

In a fourth and a fifth measurement, the screening means are formed by a mesh finer than the mesh used in the second and third measurements. Similar measuring results are obtained in the disconnected situation (open switch 17) and in the connected situation (closed switch 17), i.e. the potential differences in the tube portion between the electrodes 16a-16b (the metal elements 4a-4b) are smaller in the closed position of the switch 17 than in the open position of the switch.

In the closed position of the switch 17, the intercepted ionic fluxes are directly discharged to earth.

It will be apparent that an effective system can be realised with the aspects as explained above and defined in the appended claims, wherein the cooling element 4 that is usually electrically insulated from the ship can be protected against attack by stray current corrosion in an effective manner. As a result, the life span of the well cooler 3 is extended and the cooling efficiency is increased, because the well cooler is prevented from being affected not only by stray current corrosion bu also by fouling caused by algae, cockles, mussels etc.